AD656187

NEW FLUOROCARBON INSULATION COMPOUNDS

presented by

W. L. GORE

W L. GORE & ASSOCIATES, INC.

555 Paper Mill Road, Newark, Delaware

at the

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GENERAL

While PTFE (Teflon) possesses nearly all the attributes of an ideal material for wire insulation, there are a few respects where improvement is desirable.

One of these is in plastic flow. When PTFE resin is subjected to compressive stresses approaching its yield strength, a "plastic flow" occurs over a period of time that may cause clamped wires to loosen, and in extreme cases, may result in cutting through the insulation and shorting of the conductor. This plastic flow is found in all flexible dielectric materials to a greater or lesser degree. PTFE is less subject to plastic flow at elevated temperature than most other materials, but improvment is still needed in this property.

Another characteristic needing improvement is resistance to abrasion. The abrasion resistance of PTFE is comparatively very good and most types of *rubbing* friction result in no appreciable wear of the material. However very sharp edges of metal parts and rough surfaces will wear through PTFE insulations that are rubbed against them. Additional resistance to abrading conditions is desirable.

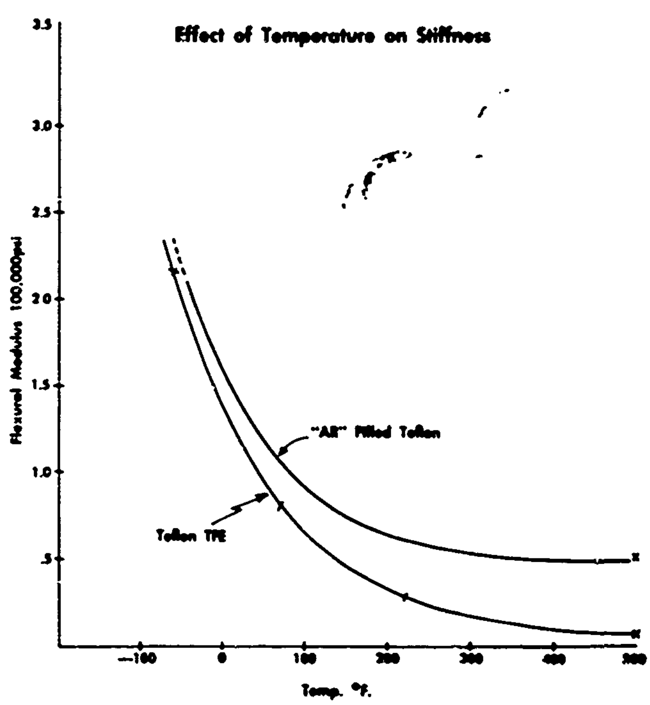
When corona discharge is set up against a PTFE surface, the discharge penetrates through the material, resulting in an insulation failure. The voltage gradients to set up corona discharge are surprisingly small, particularly at high altitudes. All solid dielectric materials suffer penetration and failure under corona discharge but certain compounded polyvinylchloride, silicone, and elastomeric materials have longer life under corona discharge than resins such as PTFE, polyethylene, and polychlorotrifluoroethylene. Where high voltage stresses are encountered (or moderate voltage stresses at high altitude) improvement is needed in the corona life of PTFE insulations to provide the nearly absolute reliability required in many complex electronic systems.

Several new compounds and wire constructions of PTFE have been developed to extend further the use-conditions under which this remarkable material can be used and reliable performance obtained.

ABRASION RESISTANT (AR) COMPOUND

The "AR" Teflon composition contains mineral fibers dispersed throughout the resin. The mineral fibers are about 1 micron in diameter and 1000 microns in length. Either glass or ceramic fibers are suitable. The fibers are mostly dispersed individually though perhaps 20% of the fibers may be present in the form of small clumps. In any case the individual fibers are highly oriented in planes parallel to the surface of the insulation. We believe this orientation of the fibers enhances the reinforcing effect. A sharp cutting or abrading edge pressed into the insulation encounters a mat of the fibers laid sideways to the cutting edge so they offer a maximum of resistance to penetration and to tearing or rupture of the insulation. Furthermore, the fibers oppose plastic flow of the resin, particularly along the direction of their orientation. The relative improvement contributed by the fibers to mechanical strength is much greater at high temperature. Figure I indicates that the stiffness of the "AR" composition is little changed from straight PTFE at low temperatures, but the drop-off is much less as the temperature increases upward above room conditions. The tensile strength of "AR" likewise shows major im-

FIGURE I



provement over straight PTFE at elevated temperature (Figure II), and the elongation is little affected.

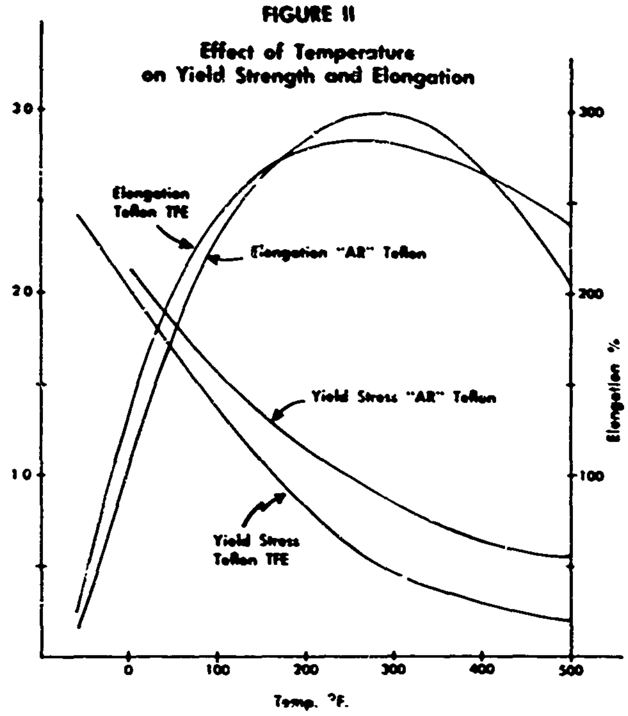


FIGURE II
Effect of Temperature on Yield Strength and Elongation

Perhaps the most important property improvement of the "AR" composition is in resistance to cut-through at high temperature. The load on a .010" radius, 90° corner steel bar required to press it through the insulation within a 10 sec. time period is plotted in Figure III. The "AR" composition loses

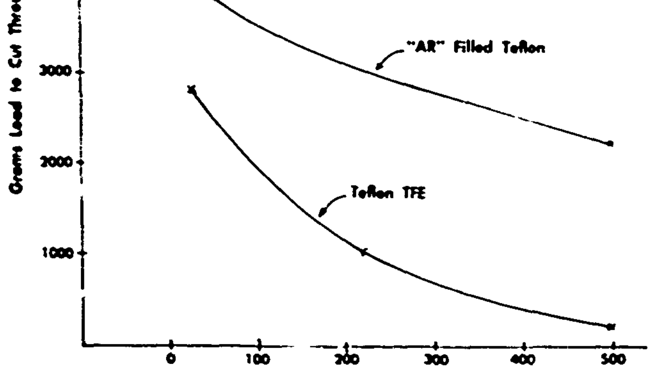


FIGURE III
Load on .01" Radius Edge to Cut Through Insulation on AWG 22 Type E Wire

little in cut-through resistance with increasing temperature, while the straight PTFE insulation becomes relatively soft and easy to cut through.

High-spot tests made at 350°C and 400°C show that a fair degree of mechanical strength is retained by the "AR" composition even above the 327°C melting temperature of PTFE.

The abrasion resistance of "AR" composition is also greatly improved over straight PTFE, and also over glass braids of equal thickness. The relative abrasion

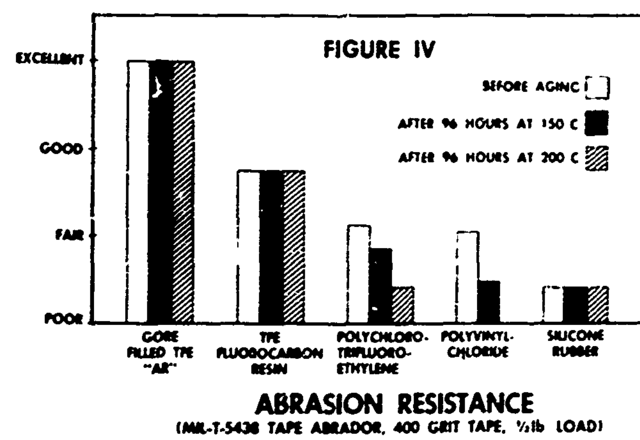


FIGURE IV
ABRASION RESISTANCE
(MIL-T-5438 TAPE ABRADOR, 400 GRIT TAPE, ½lb LOAD)

resistance of several insulating materials is portrayed in Figure IV.

Table I tabulates a typical test comparing the abrasion resistance of "AR" composition with straight PTFE.

Table 1—ABRASION RESISTANCE UNDER NAS 703

Trial No.	Standard PTFE	Mono-Tet Type AR
1	36*	48*
2	36*	54*
3	36*	60
4	42	48*
5	36*	54*
6	30*	66
7	42	60
8	42	60
Average	37*	56*
RATING*	35 in.	52 in.

*Rating is obtained by calculating the mean of the average value and all values equal to or lower than it.

Tests were made on wires having 22E-type conductors and insulation to make overall outside diameter 0.050 in.

Procedure as specified in NAS 703 is to pull abrasive cloth tape across the insulation with a specified load pressing the tape against the wire. Values are expressed in inches of tape required to wear through the insulation and short the conductor.

The above tests were with a ½-lb. load and 400 grit abrasive cloth, using MIL-T-5438 apparatus.

NAS 703 calls for a minimum rating of 48 in. Data reported here are typical in that standard Teflon insulations normally fall below this requirement.

The mineral fibers in the "AR" composition have only a minor effect on the electrical properties of PTFE. The comparisons are given in Table II.

Table 2—ELECTRICAL PROPERTIES OF PTFE

	Dielectric Constant	Dissipation Factor	Volume Resistivity
PTFE	2.0 to 2.05	0.0003	$>10^{18}$ ohm/cm
AR	2.1 to 2.15	0.001	$>10^{15}$ ohm/cm

The "AR" composition makes feasible the design of insulated wire tailored for high reliability under difficult environments. Proposed specifications have been prepared for a system of insulated wires using the "AR" composition. The dielectric strength, insulation flows, and abrasion sections of this proposed specification are as follows:

3.3.1 Dielectric strength: The finished wire shall pass the dielectric strength test specified in MIL-W-16878C, Section 4.4.2.1, except that the voltages used in the test shall be those scheduled below.

VOLTAGE FOR DIELECTRIC STRENGTH TEST AND MAXIMUM USE VOLTAGE:

Insulation Thickness	Dielectric Test	Max. Working Voltage
.010"	2,000 Volts	600 Volts
.015"	3,000 Volts	1,000 Volts
.020"	4,000 Volts	1,500 Volts
.025"	5,000 Volts	2,000 Volts

3.3.2 Insulation Flaws: All finished wire shall be 100% inspected for flaws by passing the wire through a conductive water bath with the voltage scheduled in Table II impressed between the conductor and the water bath. The wire shall be subjected to the voltage for at least 1 second. The wire shall be cut at any point where a flaw is found.

3.4.1 Abrasion: The test method shall be in accordance with MIL-T-5438 except that certain constructions shall use aluminum oxide abradant, 400 grit. The finished wire shall meet the specifications tabulated below.

ABRASION RESISTANCE

Insulation	Inches	Type Tape	Wt.	Bracket	Tension
.010"					
AWG 26, 28	24"	400 grit	.5 #	A	1#
" 24, 22, 20	42"	" "	.5 #	A	1#
" 18, 16	30"	" "	.75#	A	2#
" 14	42"	" "	1.25#	B	2#
" 12	60"	" "	1.25#	B	2#
.015"					
AWG 28, 26	30"	400 grit	1.0 #	A	1#
" 24, 22, 20	48"	" "	1.0 #	A	1#
" 18, 16	36"	" "	1.25#	A	2#
" 14	30"	" "	1.5 #	B	2#
" 12	36"	" "	1.5 #	B	2#
.020"					
AWG 22, 20	24"	150 grit	1.0 #	A	1#
" 16, 18	30"	" "	1.0 #	A	2#
" 12, 14	18"	" "	2.0 #	B	2#
" 8, 10	24"	" "	3.0 #	B	2#
.025"					
AWG 22, 20	30"	150 grit	1.0 #	A	1#
" 16, 18	30"	" "	1.5 #	A	2#
" 12, 14	24"	" "	2.0 #	B	2#
" 8, 10	24"	" "	3.0 #	B	2#

When "AR" composition is exposed to very high temperatures (as in a fire), the PTFE is volatized leaving a mat of mineral fibers around the conductor. This mat affords some protection against shorting of conductors by maintaining physical separation of the conductor from other leads and from ground.

CORONA RESISTANT (CR) COMPOUND

When corona discharge is set up at the interface of the conductor and insulation, within a micro-cavity in the insulation, or at the outside surface of the insulation, each ion impact against the insulation causes a dent or burned-out spot in the insulation. This enlarges the corona cavity, increasing the ion discharge intensity, and finally the cavity breaks through the insulation and dielectric failure occurs.

The "CR" composition contains a small amount of additive dispersed in the PTFE as small particles of very finely divided material averaging about 1 micron in diameter. Under the ion impact of corona discharge the dispersed material does not decompose to form gases as with most substances, but forms a liquid This liquid provides a film over the surface being bombarded by hot ions and the film is self-healing so that the growth of the corona cavity is slowed down very greatly.

The dispersed material in "CR" composition is white in color and tends to "wash out" pigment colors, making them somewhat pastel in shade.

The improvement in corona resistance of PTFE insulation makes possible substantial upgrading of dielectric strength ratings. Insulated wire with .005" insulation of "CR" composition is now being manufactured successfully to pass the 2200 volt RMS water bath test specified in MIL-W-16878C for type E wire with twice this thickness of straight PTFE. Wire with .010" of "CR" insulation is being supplied to 4000 volt water bath test and .015" insulation to 10.000 volt test. The elimination of rapid corona failures in water bath tests has also made feasible the manu-

facture of long lengths. Even using 100% water bath testing, continuous lengths average better than 500 feet.

The corona life of "CR" insulation is compared in Figure V to that of straight PTFE. The average life of comparable constructions is more than 100 times greater with the "CR" insulation.

A particularly interesting construction is obtained by using "CR" composition as a primary insulation and "AR" composition as a jacket. This construction, shown in Figure VI, combines the excellent corona resistance of "CR" composition with the abrasion and cut-through resistance of "AR" composition.

By improving the resistance of PTFE to cut-through, abrasion, and corona discharge, the utility of this remarkable insulating material is extended into new areas of high-temperature and high-voltage use. Also the reliability of performance in present applications is enhanced by the "CR" and "AR" modification.

Although patent applications have been filed covering the "AR" and "CR" compositions and the processes for manufacturing them, there are at present no issued patents. Therefore we are keeping confidential the details of composition and manufacturing processes.

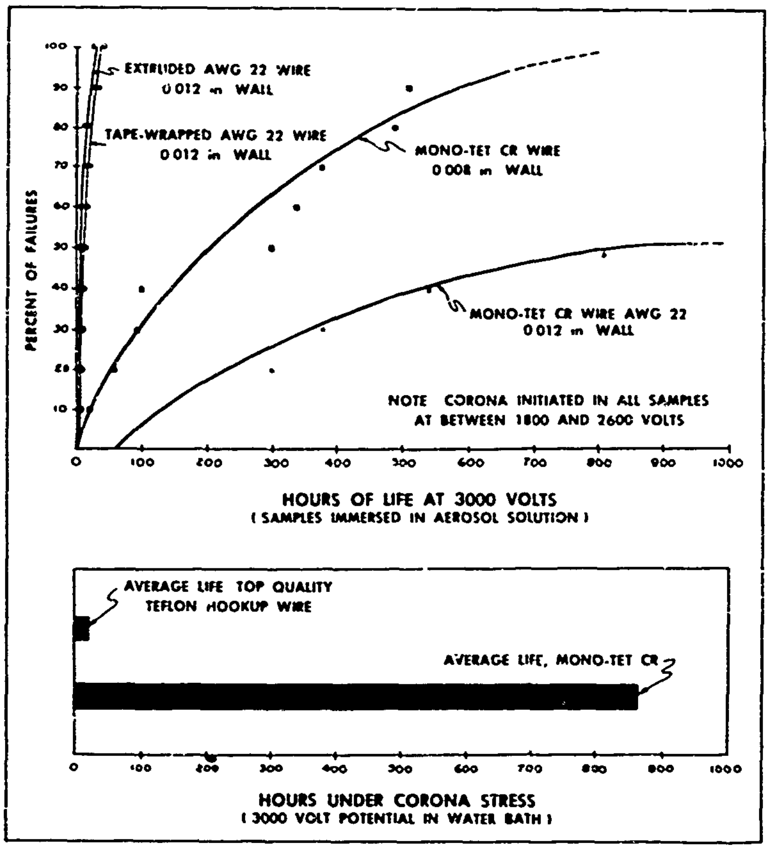


FIGURE V

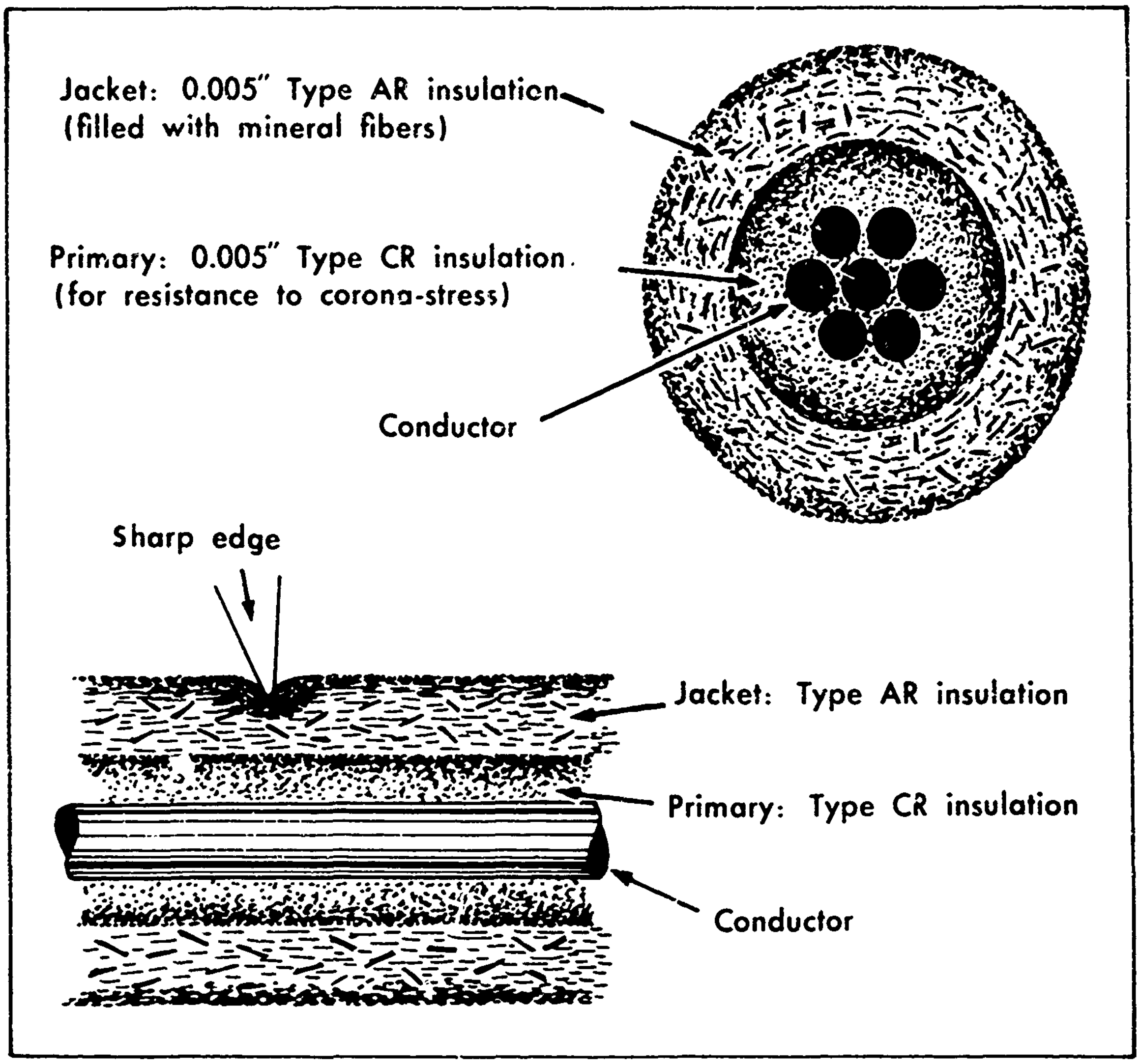

Jacket: 0.005" Type AR insulation
(filled with mineral fibers)
Primary: 0.005" Type CR insulation
(for resistance to corona-stress)
Conductor
Sharp edge
Jacket: Type AR insulation
Primary: Type CR insulation
Conductor

FIGURE VI